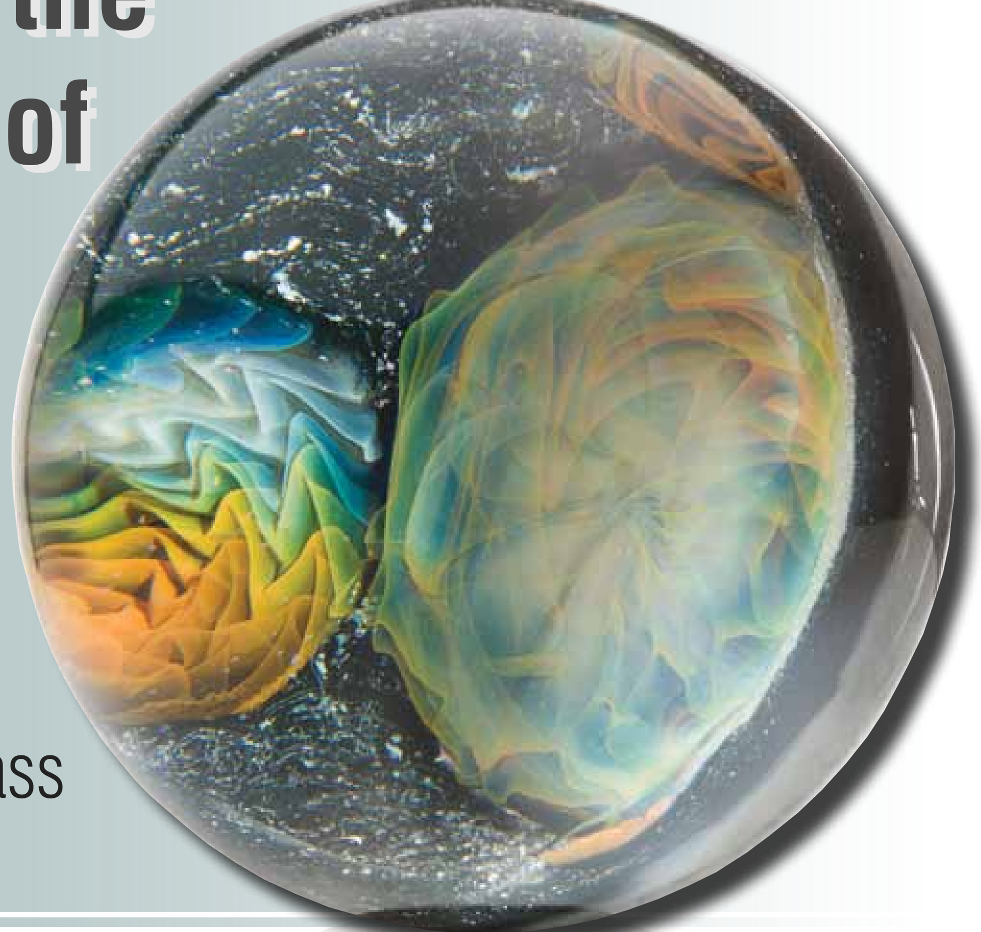
Examining the Properties of Silver and Gold



Taking an Extended Look at the Borosilicate Glass Fume Theory

by Freddy Faerron

Many thanks to all who expressed appreciation and enthusiasm for my article on my borosilicate glass fume theory and precious metal fuming in the Fall 2015 issue of *The Flow*. In this article, I want to share a few corrections and additional information. I extend my deepest gratitude to the magazine for providing this platform for dialog and creative stimulation.

Continuing Work on the Fuming Theory

First, I want to state that I made a mistake in using the terms *nanomolecular* and *nanomolecule* in my paper. That is completely different from *nanoparticle,* which is the correct term for the level we are dealing with in this work.

As I further my work in this theory—which is what I love to do, after all—I am still seeing a tremendous electric hue response when using a high oxidizing to oxidizing/neutral flame structure alongside scientific-grade tubing. I have also taken an in-depth look at the honeycomb fume data, which I would like to address in more detail.

I find the fume honeycomb dialog very intriguing, because it touches upon both the striking properties of silver and the tremendous diversity in the silver color palette. Looking at the honeycomb samples is seeing silver nanoparticles suspended in many different sizes and states of aggregation, creating a hugely diverse palette of work, which should be expected from silver nanoparticles.

Studies in Silver versus Gold Fuming

For me, a primary quandary in the theory is this: Why does silver react differently than gold? As opposed to gold, why do silver nanoparticles travel through the glass matrix during cycles of expansion (through heat) and contraction (through cooling)?

This is called phase separation in glass, and it happens both in the kiln and in the torch environment. It is a very obvious difference in my rainbow fume of silver versus gold fade studies. You can literally see the gold nanoparticles staying within the applied surface and the silver nanoparticles spreading into the matrix and shifting in hues as well as density. This has often been called “crystal growth,” which is chemically impossible within a dense matrix-like borosilicate. Crystal growth in the borosilicate matrix would be equal to a breakdown of the chemical composition and would mean that it is no longer borosilicate.

As I mentioned in my Fall 2015 article, I believe this train of thought spawned from the use of aluminum oxide in commercial borosilicate glass formulas, which inhibits the polymorphic growth of silica crystals. This is also known as “devitrification.” This is the only occurrence of crystal growth that we experience in borosilicate. When we see a large saturation of silver nanoparticles within the glass matrix, we are experiencing an aggregation at best—a gathering of nanos above the applied surface. But why and how?

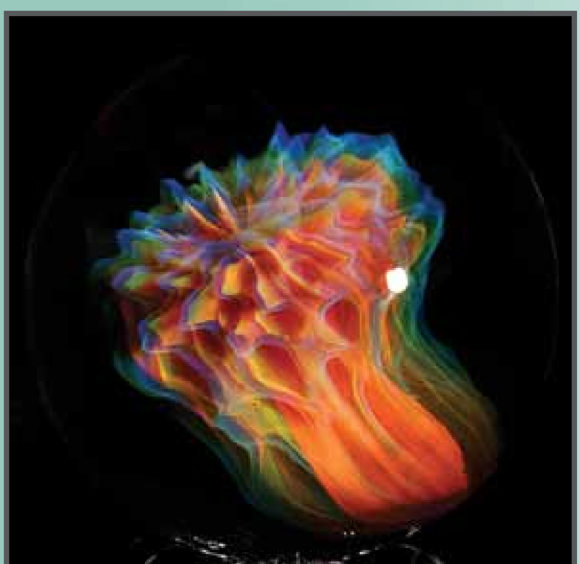
The Physics of Fuming Applications

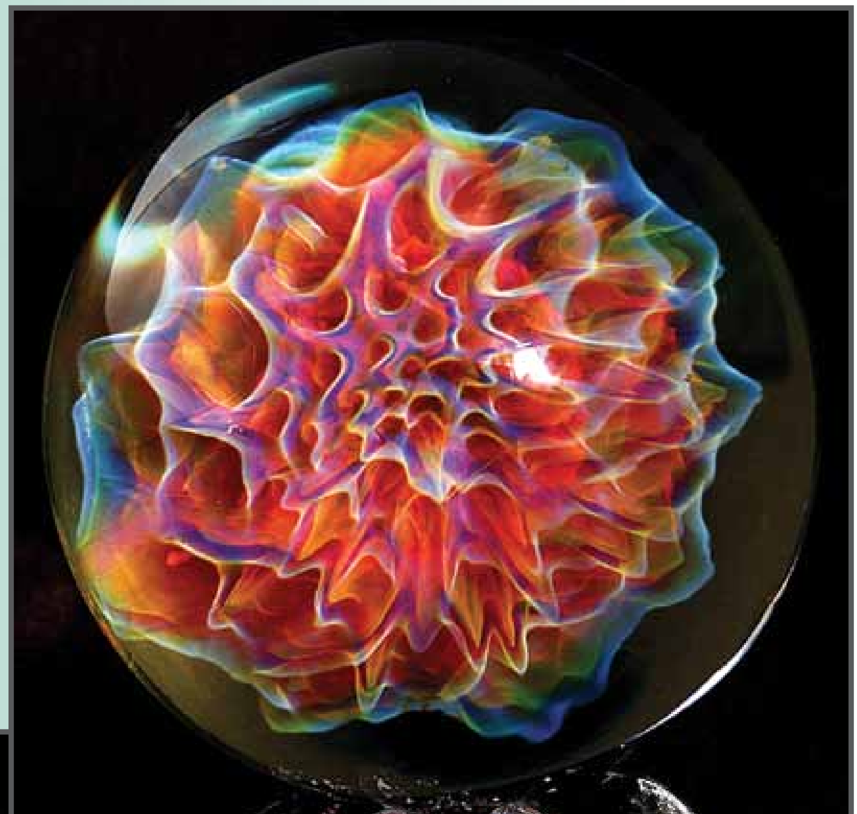
As I pondered this phenomenon, I began looking into the physics of our fuming applications. Let me state right away that I am a layperson, and physics is definitely not my forte, but the act of vaporizing the metal into the glass is something greater than a chemical reaction. I am now suspecting that what we are seeing is an electrostatic reaction. "Electrostatics deals with the phenomena and properties of stationary or slow-moving electric charges." (1)

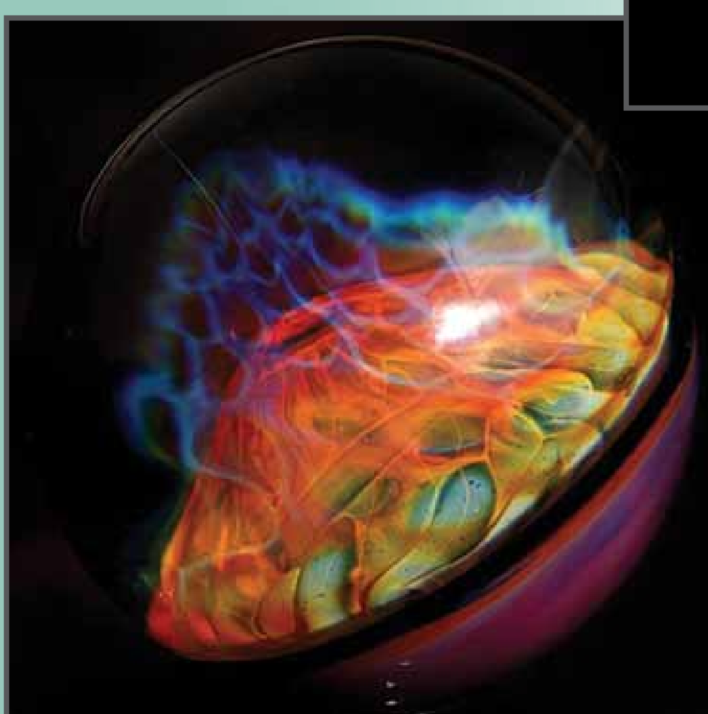
This lay understanding stems from two factors. First, I have seen that silver nanoparticles act as if they are statically charged once they are placed onto the glass. I have also noticed that through high-oxygen-based treatment of the fumed nanos on the surface, they seem to be very receptive to accepting new nanoparticle applications in an organized fashion. By this, I mean that every time I fume over a highly oxygenated base of metal, the second or multiple fume layers come out optically clear, as well as in the electric hue palette, even when I am applying multiple layers of just silver. I have always thought of it as "static cling."

(Clockwise from far left) Freddy Faerron, In Honor of Kevin O'Grady, *number 77 of 250, 4.3"; number 73 of 250, 2.1"; and number 75 of 250, 2.7". Photos by Ben Ramsey.*

When you look into the manufacture of dichroic glass, you become aware that it is also a "deposition of fine layers of metal oxides being vaporized by an electron beam in a vacuum chamber." (2) When you look at what heat is through physics, the answer can get pretty involved since it deals with the laws of thermodynamics. When defined through the kinetic energy theory, "Heat is explained in terms of microscopic motions and interactions of constituent particles such as electrons, atoms, and molecules. The immediate meaning of the kinetic energy of the constituent particles is not heat. It is a component of integral energy. In microscopic terms, heat is a transfer quantity and is described by transport theory, not as the steadily localized kinetic energy of particles. Heat transfer arises from temperature gradients or differences, through the diffuse exchange of microscopic kinetic and potential particle energy, by particle collisions, and other interactions." In short, "Heat is energy as it spontaneously passes between a system and its surroundings." (3)







Sasha Hess, Silver Honeycomb Implosion Marbles. *Photos by the artist.*

Exploring Conductivity and Thermal Expansion Coefficients

I looked into the conductivity properties of the metals, and it turns out that pure silver is the highest conductive metal in the periodic table. Copper is the standard by which electrical materials are rated, and conductivity ratings are expressed as a measurement relative to copper. Pure silver has a 105% conductivity rating, copper as the standard has a 100% rating, and gold a 70% rating. Silver also has the highest thermal conductivity rating, "the property of a material to conduct heat." (4)

It also rates a higher thermal expansion coefficient, which is the "tendency of matter to change in shape, area, and volume in response to a change in temperature" (5) as well as a lower density than gold. (6)

Theoretically, given these properties of heat and silver nanoparticles versus gold nanoparticles, we could surmise that silver nanoparticles would have a different interaction within the borosilicate glass matrix than gold nanoparticles would. The silver nanoparticles would be more conductive, more thermally expansive, and contain a lesser density than gold, which would make them act in the borosilicate matrix as they are processing the energy exchange of heat and reacting within the glass matrix through the cycles of phase separation. This reaction is what I believe we are seeing in borosilicate as the glass cools and suspends the silver nanoparticles. Borosilicate glass also becomes more conductive as it's heated.

The more I entertain this thought, the more I see it as an extremely viable explanation. It's as if the answer has been staring right back at me all along. Looking at all of the recorded silver honeycomb data—especially the electric hues shifting into this auralike appearance through cycles of phase separation—getting that hazy, distorted look comes from overstriking in the kiln. It seems to me that this highly conductive metal is experiencing its physical behavior through being excited by the energy that is heat.

The initial discussion by Freddy Faerron on the Borosilicate Glass Fume Theory can be found on page 34 in the Fall 2015 issue of The Flow.

Instagram @Freddy Faerron

Notes

1. wilipedia.org/wiki/Electrostatics
2. wikipedia.org/wiki/Dichroic_glass
3. wikipedia.org/wiki/Heat
4. wikipedia.org/wiki/Thermal conductivity
5. wikipedia.org/wiki/Thermal_expansion
6. tibtech.com/conductivity.php

Freddy Faerron has been a professional craft artist since 1990. His career has encompassed various media including leather, metal, plate glass, and lampworked glass. Freddy has traveled throughout the United States selling his art in open-air markets, craft fairs, and retail stores. His jewelry was showcased on the national TV series Dharma and Greg *and was worn in concert by Emily Saliers of the Indigo Girls.*

Working as a stained glass assembler in the mid 1990s, Freddy fell in love with glass in general. He learned from artists Bill and Irene Powell of Miami, Florida, how to cut, foil, and assemble custom stained glass panels and has continued his growth in glass art ever since. He has been lampworking full time since 1998 and specializes in metal fuming. Freddy is currently focusing on a certified implosion vortex marble series as well as solo and collaborative jewelry.

Photo by AGeekOnABike Dale Mitchell